Apparatus and System for Concrete Surface Repair and Method

by

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CROSS-REFERENCES TO RELATED APPLICATIONS

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STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

None.

REFERENCE TO A MICRO-FICHE APPENDIX

None.

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to an improved apparatus and system, and methods for use of the same, for quick and cost effective, non-impact removal of failed concrete surfaces, and replacement of the failed sections using embodiments of suspension bridge-plates, carriers, and guide/grout injection collars to repair damaged highways built of concrete slabs or pre-cast concrete slabs.

Using the system of plates and carrier of the present invention, a crew of possibly as few as two individuals could quickly and safely remove damaged slabs and replace the removed

slabs with new, pre-cast concrete slabs. Importantly, by virtue of equipment designed for this operation specifically, this system addresses the entire operation much faster than the art. The system, apparatus, and methods of the present invention provide precision location and alignment for replacement slabs, as well as a more uniform density and distribution of underlying substrate fluid binding materials for support of the replacement slabs. Highway downtime for these heretofore complicated repair procedures is lessened by the present invention, minimizing traffic driver frustration and negative impact on local economies.

Description of the Related Art

A search of the prior art located the following United States patents and publications which are believed to be representative of the present state of the prior art: U.S. Patent No. 6,595,718, issued July 2003; U.S. Patent Publication No. US 2003/0053861 A1, published March 2003; U.S. Patent No. 6,422,784 B1, issued July 2002; U.S. Patent Publication No. US 2001/0018006 A1, published August 2001; U.S. Patent No. 5,269,630, issued December 1993; U.S. Patent No. 4,591,466, issued May 1986; and U.S. Patent No. 4,507,069, issued March 1985.

BRIEF SUMMARY OF THE INVENTION

Concrete surfaces have been used extensively for the past fifty years as an economically attractive alternative to other construction materials. The interstate highway system and many

state highways feature concrete roadway surfaces. In California, for instance, there are over 10,000 miles of pre-cast concrete slab highways. Most major airport runways are concrete. The majority of California's concrete slab highways were constructed between 1950 and 1970, with an expected slab life of 20 - 25 years. Most of the concrete slab highways and many of the airport runways in the United States were built at least thirty years ago. All are in need of repair to one degree or another.

Due to unforeseen traffic volume, traffic weights beyond the surface design specifications, and age, these concrete surfaces are failing. Once failure occurs, replacement of the failed section of concrete surface is a necessary, time consuming, and costly process. Concrete surface replacement methods in the art use impact removal methods for the failed concrete surfaces. After the failed concrete surface is removed, quick setting concrete or pre-cast concrete slab installation is used in the art.

Present impact removal methods, such as use of jack-hammers or jack-hammers attached to front-end arms of Bob-cat type equipment, often have significant negative impact on the roadbed base compaction, leaving the replacement section inadequately supported.

On-site, poured concrete replacement methods in the art require lengthy downtime of the highway system. This general quick fix of pouring the concrete directly on site requires specialized concrete formulations. They also take one to two

days to completely cure before traffic can resume over the repaired section. Fast setting concrete formulations present added transportation and application costs and are expensive in themselves. They are unpredictable and sensitive to slight climactic variations. Occasionally delays such as traffic congestion cause the concrete to set up in the cement mixing truck in transit.

Placing pre-cast slabs into the spaces created by removing the failed concrete sections decreases roadway downtime, lowers repair costs, and provides longer replacement slab life over on-site poured concrete methods and systems. However, using methods and apparatus in the art, pre-cast slabs present transportation, handling, and placement costs and related problems. These pre-cast slabs, once in the hole created by removal of the failed concrete, are raised or "jacked up" by injection of a fluid binder material through holes drilled through the slab and/or from the slab perimeter to form a monolithic bulbous load supporting member to support the slab to match the planar surface of the surrounding, adjacent slabs. The "jacked-up" injection methods in the art begin injecting fluid binding material such as grout or foam under one end of the replacement slab and continuing the injection down and back on the slab length until the slab top surface is visually aligned with surrounding concrete surfaces. These methods are both time consuming and lack precision. Tolerance clearance around replacement slabs are approximately one inch plus or minus, while the void under the

slab can be a little as one-quarter inch. Since slab surfaces range from 150 - 200 square feet, these clearance and void dimensions are, relatively, quite small. Vertical sag of approximately 2.5 percent in the center of the replacement slab could put the replacement slab in direct contact with the supporting roadbed. The contact results in an uneven distribution of load spreading grout and a corresponding high potential for early for early replacement slab failure. Accordingly, even grout distribution between the roadbed and the replacement slab requires no replacement slab sag.

The grout or foam interface between the slab and roadbed needs to be applied as evenly as possible to create a uniformly distributed and uniformly dense grout interface to support the pre-cast replacement slabs evenly on the underlying road base. Voids or less dense areas of grout or foam under the replacement slabs could cause them to fail under the sudden weight loads of vehicular traffic traveling over the replacement slabs. The quick on/off force of traffic at speeds above 50 miles per hour acts as a giant jack hammer exerting forces of up to 18,000 pounds per axle, repeatedly pounding the slab. This repeated pounding leads to slab demise and negatively impacts the direction of cars traveling on the road surface.

It is, therefore, an object of the present invention to repair concrete surfaces without impacting the supporting sub-surface base.

It is another object of the present invention to

mechanically guide the replacement concrete slab precisely into proper position in the concrete surface space to be filled including, but not limited to, surrounding unaffected concrete surfaces and relative to the underlying supporting roadbed.

It is yet another object of the present invention to decrease the time required to replace failed concrete surfaces over the art.

It is still yet another object of the present invention to decrease the costs associated with replacing failed concrete surfaces over the art.

A further object of the present invention is to simplify replacement of failed concrete surfaces and to do so more safely.

Yet another object of the present invention is to minimize the disruption of regular traffic flow attendant to replacement of failed concrete surfaces.

Other features, advantages, and objects of the present invention will become apparent with reference to the following description and accompanying drawings.

BRIEF DESCRIPTION OF DRAWINGS

Fig. 1 is a top view of a broken concrete slab removal plate of the present invention.

Fig. 2 is a sectional side view of a broken concrete slab removal plate of the present invention attached to a broken concrete highway slab as depicted in Fig. 3.

Fig. 3 is a top view of a broken concrete slab removal plate of the present invention attached to a quarter section of a

broken concrete highway slab cut into quarter sections approximately 6 feet in width by 7 1/2 feet in length.

Fig. 4 is a top view of bridge slab replacement apparatus of the present invention which allows the replacement slab to be suspended over the placement hole creating a small 1/4 inch to 1/2 inch void for the grout interface, and which allows the replacement slab to be aligned with surrounding planar surfaces of the highway.

Fig. 5 is a side view of the bridge slab replacement apparatus of Fig. 4.

Fig. 6 is a bottom view of an embodiment of precast concrete replacement slab of the present invention showing channels to facilitate even and uniform grout input across the entire slab bottom without holes or air pockets.

Fig. 7 is a side view of the channels of the precast concrete replacement slab of Fig. 6.

Fig. 8 is a side view of an embodiment of replacement slab carrier transport trailer of the present invention in travel mode using a chain hoist and rotational roller mechanism to rotate, raise, and lower a replacement slab.

Fig. 9 is a top view of the embodiment of replacement slab carrier transport trailer of the present invention depicted in Fig. 8.

Fig. 10 is an end view of the embodiment of replacement slab carrier transport trailer of the present invention depicted in Fig. 8.

Fig. 11 is a side view of an embodiment of replacement slab carrier transport trailer of the present invention in travel mode showing stabilizing bars employed.

Fig. 12 is an end view of rotated slab showing stabilizing bars positioned and employed thereon.

Fig. 13 is a top view of an embodiment of bridge weight plates of the present invention affixed to a replacement slab in transport mode.

Fig. 14 is a top view of an embodiment of replacement slab carrier transport trailer of the present invention in travel mode.

Fig. 15 is a top view of an embodiment of replacement slab carrier transport trailer depicted in Fig. 14 in slab replacement mode.

Fig. 16 is an end view of an embodiment of replacement slab carrier transport trailer depicted in Fig. 14 in slab replacement mode.

Fig. 17 is an end view of an embodiment of replacement slab carrier transport trailer depicted in Fig. 14 in travel mode.

Fig. 17A is a detail of the rotating mechanism of the carrier transport trailer of Figs. 14 - 17.

Fig. 18 is a side view of an embodiment of replacement slab carrier transport trailer depicted in Fig. 14 - 17A in slab replacement mode wherein the carrier wheels are off the ground and the full weight of the carrier, plate, and slab is available to counter uplift from fluid binder material deemed necessary to

provide even, complete, and uniform distribution of the binder material interface.

Fig. 19 is a side view of an embodiment of replacement slab carrier transport trailer of depicted in Figs. 14 - 17A in travel mode.

Fig. 20 is a side view of guide ramp assembly to position a replacement slab carrier transport trailer for slab placement.

Fig. 21 is a sectional view of the wheel channel ramp of the guide ramp of Fig. 22.

Fig. 22 is a top view of the guide ramp assembly of Fig. 20.

Fig. 23 is a top view of an embodiment of an adjustable slab replacement plate of the present invention depicting grout injection and guide collar and extensions, wherein the collar is shorter than the replacement slab to accommodate differing sizes of replacement slabs.

Fig. 23A is a sectional view of the grout injection and guide collar and extensions of Fig. 23.

Fig. 24 is a top view of insert corners for the embodiment of grout injection and guide collar and extensions depicted in Fig. 23, whereby removable insert pieces are bridged one-to-another and onto the main injection collar.

Fig. 25 is a side view of an embodiment of replacement slab carrier transport trailer of the present invention in slab replacement mode.

Fig. 26 is a side view of an embodiment of replacement slab carrier transport trailer depicted in Fig. 25 in slab replacement

mode wherein the carrier wheels extend outward from the plate/slab assembly lowering the carrier frame and transferring substantially most of the full weight of the carrier to the plate/slab assembly to counter uplift from the grout pressure to provide even, complete, and uniform distribution of the grout layer interface.

Fig. 27 is a top view of an alternative embodiment of bridge slab replacement apparatus of the present invention showing a cross-member, extension arm assembly.

Fig. 28 is a top view of another embodiment of bridge slab replacement apparatus of the present invention showing alternative sizing and anchoring points for bridge plates.

Fig. 29 is a top view of a preferred embodiment of bridge slab replacement apparatus of the present invention showing a bridge plate with weights/anchoring devices.

Fig. 30 is a top view of an embodiment of bridge plate assemblies showing alternative sizing and anchoring points for alternative bridge plates.

Fig. 31 is a side view of a preferred embodiment of bridge slab replacement apparatus of the present invention showing a bridge plate with weight/anchoring device and grout injector collar.

Fig. 32 is a side view of an embodiment of bridge slab replacement apparatus of the present invention showing a grout injection and guide collar with grout slot and attachment lip.

Fig. 33 is a top view of an embodiment of bridge slab

replacement apparatus of the present invention showing a perimeter collar with holes or slots for grout injection.

DETAILED DESCRIPTION OF THE INVENTION

The apparatus and system of a preferred mode of the present invention removes broken concrete surface slabs in four lifts or less. As shown in Fig. 1, an embodiment of the present invention uses a rectangular broken concrete slab removal plate **10** approximately 7 feet by 8 feet, or slightly larger than a quarter section of highway slab. The removal plate **10** can be various sizes or geometries, even as large as an entire highway slab. The removal plate **10** is made of solid material comprising a substantially uniform thickness, plate edge boundaries, a planar plate top surface and a planar plate bottom surface. The rectangular removal plate **10** of the 7 feet by 8 feet dimension of this embodiment is a block of material, such as metal, high strength poly-carbon, or the like, thick and strong enough to support weights of approximately 5 tons for removal of quarter-cut concrete slabs.

The removal plate **10** further comprises a plurality of small diameter openings or holes **12** drilled through the plate **10** wherein each hole diameter defines a centerline perpendicular to the plate planar top and bottom surfaces, and crane pick points **14** at the removal plate **10** edge boundaries, or at the four corners of the removal plate **10**, and/or at mid-points on each of the removal plate's **10** four sides. An embodiment of the invention provides as many holes as solid surface depth, yielding

a 1:1 ratio of holes to solid removal plate **10** metal material. Interior pick points **14** could be added depending on the particular circumstances and geometry of the slab removal. The larger sized plate **10**, also can be used once affixed to a replacement slab to align the replacement slab to planar surrounding slabs and to suspend the replacement slab creating smaller interface voids between the replacement slab bottom surface and existing supporting roadbed by having the length of the plate **10** overlap onto each of the planar slabs surrounding the replacement slab. Alignment of the replacement slab in the traffic flow direction, which generally is along the longitudinal axis of the replacement slab, is most critical.

As depicted in Figs. 2 and 3, the plate **10** is securable to the broken concrete highway slab **1000** planar top surface by anchors **16** bolted through the one or more of the plurality of small diameter openings or holes **12** drilled through the plate **10** and into the slab **1000**. Fig 3 shows a typical removal plate **10** arrangement of the present invention attached to an approximately squarish shaped, cut quarter broken concrete highway slab segment **1000**. The irregularity of sizes created by concrete failure indicated along crack-line faults normally makes it difficult to secure the odd shapes for broken slab removal. Contact over the entire broken slab surface with an appropriate number of approximately evenly distributed anchors resolves this engineering dilemma. Snugging the broken pieces to the plate prevents torque twisting that easily could result in anchor rod

failure. This feature of the present invention greatly improves the removal characteristics over adjustable frame type removal apparatus in the art. By virtue of the 100 percent surface contact, torque twisting is also eliminated for irregular slab segments not perfectly centered according to the center of mass of the slab segment. The continuous surface interface of the plate **10** bottom to slab **1000** top planar surface, combined with anchors **16** securing the same interface, prevents any lateral, twisting or moment force on the anchor points **16** as the slab **1000** is lifted. Adjustable frame inventions in the art require nearly perfect weight adjustment to the centroid to avoid these forces, a complex on-site engineering adjustment problem created by the irregular shapes of broken concrete. For most applications in this system a couple or several anchor points **16** secured into each broken slab **1000** segment through the plate holes **12** provides adequate anchor strength and slab support from the removal plate **10**. These anchor points on broken irregular slab pieces need not be positioned with engineering calculations to account for a weight centroid, but rather are spread evenly by visual alignment across the irregular shape.

The removal plate **10** unifies and strengthens the cut section of broken slab **1000** into one piece allowing safe and quick removal of the damaged slab **1000**. The broken pieces of the slab cannot move vertically or horizontally. They are secured to the removal plate **10** across the entire bottom removal plate **10** planar surface. The stability of the slab so attached minimizes the

likelihood of anchor failure while the slab is being removed by allowing for shorter anchor bolts than those used for a frame type apparatus. There is little tensile strength in these lifting coil rods. The snug fit at multiple locations also prevents the twisting torque moments irregular shapes and weights might produce which would also likely cause anchor rods to fail.

Concrete highway slabs in the United States typically range from 8 inches to 12 inches in depth. These slab depths may vary widely in other countries depending on expected loads and the environment of the roadbed. The preferred method of the system of the present invention is to cut the broken concrete highway slab **1000** into quarter sections, Fig 3, approximately 6 feet wide by 7 1/2 feet long by 10 inches deep. Cut broken concrete slab sections of these dimensions are manageable, and fit easily and safely into removal transport vehicles using small lifting cranes. Failed concrete slabs can be cut using large, circular concrete saws in the art. Or cuts can be precisely and speedily performed using jig saws, laser saws, or water jet saws in the art. Use of these saws are combined with global positioning technology to input the precise cut location to a microprocessor database. This database includes, among other necessary data, the size and depth of cut, the size and depth of slab, and the precise location of the cut. The improved laser or water jet cutting means also eliminate short-comings the rotary concrete sawing methods in the art.

Rotary saws in the art are slow, operator sensitive, and

prone to jamming and blade breakage. Slab cut measurements by rotary saws are by nature imprecise. A typical rotary saw cut is made three times with differing diameter saw blades ranging from small, about 16 inches, to large, about 36 inches. At the boundary edges of the broken slab to be removed, the rotary blade cuts into surrounding slabs as it reaches the perimeter bottom of the broken slab. This invasive cutting action weakens these unbroken slabs. Typical rotary blade costs are approximately $3,000.00 for large blades used to cut highway sized concrete slabs. Rotary saw blades wear fast, are expensive and prone to breakage, and are especially sensitive to operator skill. Thus, in keeping with the improved efficiency and safety of the system and apparatus of the present invention, improved slab cutting means are pursued.

Full sized highway concrete slabs are too wide for regular transport, and require a special sized vehicle with the appropriate "wide load" warning signs displaced on the front and rear of each such vehicle or pilot vehicles accompanying the oversized vehicle displaying similar road hazard warning signs. The slab cutting step of the present invention reduces handling weight of the slab removal and also reduces the size of the removed broken concrete slabs. The removed quarter section slabs can easily fit into the bed of standard sized dump trucks or other transport vehicles. There is no need for special sized flatbed trailers, nor extra pilot-vehicles to accompany such over-sized loads traveling down highways. The containment

requirements presented in the art for over-hanging portions of whole broken slab extending two feet on each side of a flatbed removal transport are also eliminated by use of the slab cutting step of the present invention.

The plurality of holes **12** in the removal plate **10** of the present invention allow anchoring by expanding dead bolt, threaded receivers **16** to be easily adjusted into patterns which best adhere to and hold each of the irregular pieces of broken slab segments within the quarter section of the cut highway slab **1000** marked for removal and repair, Fig. 3, in one cohesive unit. The removal plate **10** of the present invention can accommodate a plurality of varying sized expanding dead bolts. For example, a standard 5/8 inch expanding dead bolt cannot be placed within one foot of the perimeter of a broken slab segment; however smaller expanding dead bolts, down to 1/4 inch can be placed closer to the broken slab segment edge. The removal plate **10** of the present invention is flexible and secure enough to support all relevant sized holes drilled into the broken slab segment. This feature improves the slab removal apparatus or methods in the art, particularly adjustable frames, where slot channels must nearly touch anchor rod sides to prevent breakage of the rods due to torque forces and the long rod lengths. The present invention avoids this type of failure by having plate holes larger than the largest slab drilled hole, approximately 5/8 inch. Thick overlapping washer type pieces of metal or other suitable strong material with a circular insert lip fitting the plate hole are

used with these oversized plate holes, centering the plate hole for the anchor rod selectively sized for use.

Crane lift requirements also are reduced by the present invention to approximately 5 tons. By placing the flat quarter sections of broken slab segments into a removal vehicle, and then walking onto the removal plate **10**, unbolting the removal plate **10**, and lifting the removal plate **10** by crane from the removed flat quarter section of broken slab segment **1000**, the debris intensive methods of jack-hammered slab removal in the art are avoided. The removed flat quarter sections of broken slab segments readily are stacked one-upon-another, until the load limits of the respective removal vehicle are reached. Additionally, since jack hammering is not necessary for the system of the present invention, the underlying roadbed is not impacted by removal of the broken concrete slab.

Methods of slab replacement in the art throw replacement slabs onto the ground and then jack-up the replacement slab by injecting binder material through holes drilled through the replacement slab until the replacement slab matches its surrounding planar surfaces. This jockeying of slab requires several men and considerable time to properly complete the process. Even so, location of the replacement slab is only eye accurate or less, and there is no definitive way to insure that binder material is uniformly distributed to an adequate depth density and even consistency. Operational efficiency under these circumstances depends on an experienced crew using best efforts.

An alternate carrier or bridge plate **50** embodiment of the apparatus of the present invention is presented in Fig. 4 for positioning and installation of the replacement concrete slab **1100**. The carrier or bridge plate **50** is made from solid material comprising a predetermined geometry that is longer than the replacement slab to which the plate is joined, substantially uniform thickness, plate edge boundaries, a planar plate top surface, a planar plate bottom surface, and a longitudinal plate axis. Plate width can also be larger than the attached replacement slab; however, the critical dimension is plate length since the preferred planar alignment of the replacement slab is dictated by the flow of traffic. Plate thickness is determined by the strength needed to avoid deflection of the plate ends and downward flex due to weight in the center of the plate/slab unit. This feature of the present invention is a critical improvement over the art, namely adjustable frames which comprise beams light enough for manual adjustment but not strong enough to prevent end deflection or mid-slab sagging within the interface void between the slab bottom side and the underlying roadbed substrate. Depending on the slab surface geometry, carrier or bridge plates **50** planar bottom surfaces are affixed to the planar top surface of the replacement slab **1100** by anchors. Accordingly, the replacement slab **1100** is suspended over the roadbed. Weight can be added to the replacement slab, or as part of a bridge from the carrier or bridge plate **50** top planar surface to the substantially planar top surfaces of adjacent existing slabs

1200, as counter balance to the uplift force of high strength grout or polymeric foam pressure injected under the replacement slab **1100**. In this manner, consistent and uniform density of the high strength grout or polymeric foam so injected in ensured. Again, depending on the surface and roadbed conditions, these carrier or bridge plate **50** sizes and geometries can be varied to fit the intended purpose of keeping the replacement slab **1100** suspended above the roadbed surface, as shown in Figs. 4, 5, 27 - 30. The space between the replacement slab **1100** bottom and the roadbed can be exploited to pressure inject fluid binding materials such as high strength grout or polymer, or expanding foam more uniformly and consistently than "jacking" methods in the art. And the process of the present invention is faster than the "jacking" methods as there are no barriers or blockages met and no slab lifting to slow it down. In one embodiment, the carrier or bridge plate **50** width is nearly the width of the replacement slab **1100**, Fig. 15. In the embodiment of Figs. 4, 13 and 15, anchor points **16** are positioned through slots **15** in the carrier or bridge plate **50** so the high strength grout or polymeric foam injection collar **68** can be positioned adjustably to guide and snugly fit the up to the end of the replacement slab **1100**. This embodiment is useful for any of the varying lengths of concrete slabs used to prevent harmonic vibration caused by interaction of slab spacing and traversing vehicular traffic. There could also be slot **15** above the collar matching holes in the collar **68** for high strength grout or polymeric foam

injection. The collar **68** comprises either a "V" cross-section with a top width greater than a base width, e.g. Figs. 5, 31, or 32, or a right angle triangle geometry, with the base of the triangle flush against the replacement slab side and the hypotenuse serving as a guide element, Fig. 23A. The collar **68** could be entirely separate from the carrier or bridge plate **50**, thus necessitating holes in the carrier or bridge plate **50** through which high strength grout or polymeric foam is injected. In the separate collar embodiment, slots for the carrier or bridge plate **50** anchor adjustment are provided.

Ramps are used to locate the replacement slab as close as possible over the space vacated by the removed broken slab. Embodiments of the injection guide collar comprising either the "V" cross-section or right triangle cross-section precisely locate the last inch of tolerance. To get the replacement slab from the location provided by the ramps to be in position to fit into the space vacated by the removed slab often may require an adjustment mechanism to controllably wobble the replacement slab into position.

Once the replacement slab is rotated such that its planar top surface is aligned with a horizontal plain nearly over the space vacated by the removed slab, the hydraulic arms join the plate to the carrier spine by a heim joint connection at each end of the hydraulic arms. By slight adjustment the slab is wobbled within the horizontal plane without compromising vertical load, strength, and length until proper planar surface alignment is

achieved and verified by global satellite positioning, survey, or other means known in the art.

Another embodiment of the carrier or bridge plate **50** assembly of the present invention for positioning and installing the replacement slab **1100** is presented by Fig. 29. A central cross assembly **60** is anchored to crane pick points near the replacement slab's **1100** center. This cross assembly **60** has a plurality of separately adjustable arms **62** extending outward, and each such arm **62** has at its outward bridge end a plate **64** to rest on the adjacent existing concrete slabs **1200**. These plates **64** can be further weighted to counter balance any uplift phenomena during high strength grout or polymeric foam application, if necessary, as further shown in Figs. 4, 5, 27 - 29. The counterbalancing weights can be applied anywhere on the replacement slab **1100** as well as on the bridge end plate on an adjacent slab **64**, Fig 29, or **66**, Figs. 4 and 5. Often, the weight of the replacement slab **1100** will be sufficient counterbalance to assure that the high strength grout or polymeric foam distribution is consistent and uniform beneath the replacement slab **1100** without the need for weight on the bridge end of an adjacent slab. Thus, an even concrete highway transit surface from slab to slab is more possible. This system also minimizes any disruption to the roadbed support surface under the replacement concrete slab by suspending the replacement slab **1100** above the non-impacted roadbed.

As shown below, the proprietary, specially designed

replacement slab carrier assembly system serves both as transport and lifting/positioning apparatus. These embodiments for slab replacement eliminate the need for wide load warning requirements. Similarly, flatbed trucks to transport the replacement slab and larger lifting cranes, 15 tons or more, to position or lower the slab are not necessary using this embodiment of the present invention.

The high strength grout or polymeric foam injection collar **68**, as more specifically detailed in Figs. 5, 23, 31 - 33, serves to place the replacement slab **1100** precisely equidistant from all the surrounding existing slabs **1200**. This equidistant positioning is critical to create a uniform consistent vertical interface between adjacent existing slabs **1200**. These equidistant spaces serve as expansion joints between slabs allowing for expansion and contraction between slabs due to climactic circumstances, traffic pressure or forces, and roadbed foundation dynamics. In the art, poured-on-site replacement concrete displace these expansion/contraction joints to a new perimeter surrounding five slabs instead of one. The poured-on-site approach invites early slab failure since the potential for crack stress failure increases exponentially with size. The injection guide collar of the present invention insures uniformly even expansion/contraction joints on all sides of a single replacement slab.

The collars **68** also serve to provide service inlets for high strength grout or polymeric foam injection slots while sealing

the joints. This critical feature forces high strength grout or polymeric foam to flow under the slab, between the suspended slab bottom surface and the top of the roadbed and against the solid interface area of adjacent existing slabs, and prevents flow out of the joint. These same inlets can function as outlets, permitting measurement of the arrival of grout at the perimeter point. In this fashion, when the pressurized grout is applied internally through the slab, Figs. 6 and 7, the grout application is uniformly dense because it is injected under static pressure across the entire void between the replacement slab bottom and the roadbed.

Figs. 23 and 33 show embodiments of the collar's **68** equidistant placement surrounding a replacement slab **1100**. This feature is critical to ensure a precisely uniform joint between the replacement slab and the adjoining existing slabs. As shown, part of the collar **68** can be under the carrier or bridge plate **50**, Figs. 5 and 31, or the collar **68** may be a separate guide/group input wedge element unto itself, Figs. 23, 32, and 33. Once the high strength grout or polymeric foam has been allowed to set for a short period, the bridge plate(s) **50** and collar(s) **68** are removed from the replacement slab **1100**. The remaining open vertical space could be filled with a different, more elastic grout or any appropriate grout or binder material for expansion and contraction phenomena between the replacement slab and the adjacent slab surface edges.

Replacement slabs **1100** can be pre-cast with reverse form

patterns, such as channels, or the like, **80** to facilitate the flow of high strength grout or polymeric foam uniformly across the underside of the suspended replacement slab **1100** as shown in Fig. 6. The replacement slab channels **80** promote the high strength grout or polymeric foam to create a uniformly consistent interface layer **85** between the replacement slab **1100** and the underlying road base support surface or subgrade **1300,** Fig. 7. The interface layer **85** is critical to the life of the slab since the applied high strength grout or polymeric foam resolves irregularities on both the roadbed and replacement slab bottom to create a uniform load transmission caused by vehicular traffic pounding forces on the slab and on to the solid bedrock of roadbed surface below the slab. Thus, the uniformity of fluid binding material distribution and density is critical to replacement slab life. Any irregularities in high strength grout or polymeric foam distribution or density leads to weak points, harmonic vibrations, or other irregular pressures that could result in untimely failure of the replacement slab.

While this reverse form pattern feature may not be needed in all applications, patterning the suspended replacement slab bottom enhances fluid binding material interface between the slab bottom and the roadbed. In some instances, replacement slab **1100** thickness may be reduced 1/8 inch to 1/4 inch using the patterned replacement slab bottom technique of the present invention. These slightly thinner replacement slabs **1100** allow high strength grout or polymeric foam to cover high spots on the roadbed that

the high strength grout or polymeric foam would otherwise flow around. This minimal reduction in thickness does not effect the replacement slab **1100** strength; however, the improved fluid binding material interface increases the replacement slab life in the highway surface. The reverse foam pattern on the replacement slab bottom side, Fig. 6, also decreases time needed to push the thick, viscous binder material by providing a less restrictive environment for movement of the same between the subgrade roadbed and the slab bottom surface.

From the data provided from the laser or water jet saw cuts, each replacement slab can be precisely configured and pre-fabricated for the space in the repaired surface to which it will be suspended. Use of bar coding and global positioning technology in the system of the present invention ensures proper replacement slab placement.

Figs. 8 - 11 show an embodiment and related elements of the replacement slab transport trailer system of the present invention which facilitates installation in several ways: a) the trailer apparatus **300** can be hooked to any appropriate tractor or truck to transport the replacement slab to the designated position on a highway or concrete surface; b) 12 foot wide slabs can be rotated and transported so that the combined slab and trailer is less than the maximum 8 foot normal highway vehicle width, Figs. 8, 10, and 11; c) the apparatus can be returned to the horizontal position and then the attached plate/slab unit lowered into place, suspended above the roadbed by the plate

system, in the concrete surface being repaired, Fig. 9; and d) the carrier system can be linked to global positioning technology and/or bar code identification technology to ensure each replacement slab is suspended at the accurate location in the repaired concrete highway surface.

The embodiment of transport trailer system of the present invention depicted in Figs. 8 - 11 comprises in combination a frame capable of supporting and transporting replacement concrete slabs weighing approximately 25,000 pounds. The trailer has a longitudinal frame axis, a front frame member **316** having a top portion and bottom portion, a rear frame member **317** having a top portion and a bottom portion, and a main support beam member **314** connecting the front frame member and rear frame member by attachment to the top frame member portions. The connecting support beam provides a top surface, a bottom surface, and two side surfaces. Wheel mounting members are pivotally joined to the front frame member bottom portion and wheel mounting members are fixedly joined to the rear frame member bottom portion. A hitching tongue **318** projects forward from and is joined to the wheel mounting members connected to the front frame member bottom portion. Wheels are rotatably disposed on the wheel mounting members.

Chain, cable, or the like, **310** serve to attach the replacement slab **1100** to the roller mechanism **312** on the main horizontal support beam **314** of the carrier transport trailer **300**. The other end of the chain, cable, or the like **310**, is attached

to pick points **16** pre-placed in the pre-cast replacement slab **1100**, Fig 8. Each carrier transport trailer **300** is less than approximately 8 feet wide and 26 feet long, without hitching tongue **318**, Figs 8, 9, and 11. The rotation means allows transport of a full sized highway slab on highways without the necessity of specialized vehicles, "wide load" warning signs, and related precautions. By using global positioning technology and/or bar coding identification, or similar means, for locating replacement slabs within carriers, several carriers could be linked in the particular specific order of slab replacement required for a length of damaged surface, and slab suspension at the precise location for each replacement slab can be readily achieved.

Using removable guide ramp assemblies, Figs. 20 - 21, the tractor or truck and the carrier transport trailer **300** drive into the hole to be repaired by the replacement slab. The ramp assembly, Fig. 20, provides an approach lip **600** with a beveled end and a hinged end wherein the angle of the ramp relative to surrounding concrete surfaces **1200** is adjustable. A pair of ramps **640** are so assembled, each having a channel **650**, an outside edge, and inside edge, a ramp top, and a ramp bottom defining a predetermined uniform angle of declination from surrounding concrete surfaces, wherein the ramps are fixedly attached at a predetermined distance by at least two uniform cross members **670** affixed to the ramp inside edges. The ramp pairs are aligned within the space bounded by unaffected surrounding concrete

surfaces by manual adjustment to guide mechanisms **660** affixed to the ramp outside edges. The ramp channels and cross members are sized to receive the replacement slab transporting carriers' wheel dimensions. Steel pads **630** provide height adjustment, if necessary, to an approach support member **620** having a first hinged end attached to the approach lip **600** hinged end and a second hinged end attached to the ramp tops, a top side, and a bottom side. Support member **620** height is adjusted by placing the required number of steel pads **630** between the support member **620** bottom side and unaffected concrete top planar surface **1200**.

The truck and front trailer wheels drive down the ramps into the space and back up opposite side ramps positioning the slab accurately for any slight further adjustment and for lowering into the space vacated by the removed damaged slab. Alternatively, the carrier transport trailer **300** may employ a "lazy susan" type of connection to its axles so that the trailer can be precisely maneuvered sideway for exact placement of the replacement slab. This apparatus can be used at all the stages of the concrete slab replacement process - from pick up to delivery and installation.

As shown in Figs. 11 and 12, the carrier transport trailer **300** comprises a plurality of stabilizer bars **320** which are put into place into the frame members after the replacement slab **1100** is raised and rotated within the carrier transport trailer **300** frame. The inserted stabilizer bars project rearwards perpendicularly from the front frame member **316** and project

forward perpendicularly from the rear frame member **317**, whereby the rotated replacement slab fits between corresponding inserted stabilizer bar pairs during transport of the replacement slab. Other mechanisms attached to the carrier transport trailer **300** frame also could be used to further stabilize the suspended replacement slab **1100**. Because the replacement slab **1100** is suspended within the carrier by chain, cable, or the like, **310** side to side swinging potential is presented during movement of the carrier transport trailer **300**. The stabilizer bars **320** or other means attached to the carrier transport trailer **300** frame prevent the replacement slab **1100** from swinging side to side during transport. The stabilizer bars **320** do not support any weight of the replacement slab **1100**, and are quickly positioned within or removed from the carrier transport trailer **300** via sockets or the like positioned on and attached to the carrier transport trailer **300**. Likewise, methods for locking the slabs to the carrier for safety could be added separate from stabilizer bars, or the stabilizer bars could be enhanced to provide any necessary strength for locking the slab to the carrier.

During transport, replacement slab carrier or bridge plates **50** can be anchored in place to the replacement slab **1100**, as shown by the embodiment depicted in Fig. 13. Anchoring takes place before the replacement slab **1100** is lifted into the carrier transport trailer **300** for transport. Additional stiffeners, or transport cross links **56** can be attached to the two carrier or bridge plates **50** as may be necessary to support the replacement

slab from center sag or flex. Concrete highway slabs have enormous compression strength but limited tensile strength. Concrete slabs transported over bumpy roads without adequate back support or truck-bed support could vibrate and/or flex under their own weight and crack or break before they reach the replacement site, requiring cross-hatched rebar or the like to be placed within replacement slabs in the art. The carrier or bridge plate **50** anchoring apparatus of the present invention supports the relatively weak tensile strength of the replacement slabs **1100**, providing immense external support far exceeding internal rebar. The carrier or bridge plates **50** and stiffeners **56** add spine to the replacement slab **1100**, and prevent cracks due to flexing caused by transport pressures and handling movement. The replacement slabs **1100** are strong when flat on the road-bed surface. The transport cross links **56** function like the aforementioned stabilizer bars to prevent the replacement slab **1100** from cracking under its own weight, nearly 25,000 pounds, during transport. Since the cross links **56** are not attached to the replacement slab **1100**, they are quickly and easily removed from the carrier or bridge plates **50**. The plate depicted in Fig. 13 could also be used for replacement slab placement within the apparatus depicted in Figs. 14 - 19, 25, and 26. This embodiment of the carrier or bridge plate could effectively eliminate the need for internal rebar in replacement slabs to the extent that such materials are necessary to offset transport and placement stresses.

Other embodiments of carrier transport trailer **400**, Figs. 14 - 19, and **500**, Figs. 25, and 26, use the weight of the trailer to counter balance the uplift force of high strength grout or polymeric foam pressure injected under the replacement slab **1100**. The carrier transport trailer **400**, Figs. 14 - 19 comprises mechanism means **450** to raise and lower and rotate the replacement slab **1100**.

In the transport mode, the carrier transport trailer **400**, Figs. 14, 17, 17A, and 19, supports the replacement slab **1100** in a position rotated to a width of approximately 8 feet and a height less than 11 feet, Fig. 24, by a central support spine **420**. The central support spine **420** comprises one mechanism means for lowering/lifting and another for rotating **450** the replacement slab **1100** which is anchored to a support plate **480** by a plurality of anchors **482**. The support plate **480** is supported by swivel anchors **484** each of which are connected to its separate, corresponding mechanism means for rotating **450** the replacement slab **1100**. One embodiment of the present invention provides hydraulic ram arms as means for rotating **450** the replacement slab **1100**. These hydraulic ram arms **450** are paired in the sets evenly spaced along the sides of the carrier central spine **420**, Figs. 14 - 15. The end pairs of hydraulic ram arms **450** carry the weight of the plate/slab mass in lowering the plate/slab mass. The center hydraulic rams serve as anti-flex members to maintain the substantially planar orientation of the slab top surface. All six hydraulic ram arms **450** serve to rotate the plate/slab mass,

and secure the mass during transport. Plate **480** and central spine **420** strength and thickness are determined by the need to offset downward gravity deflection or sag to within hundredths of an inch increments. The hydraulic arms **450** on one side of the central spine **420** which function only in a vertical axis are joined to the central spine **420** by a rigid support bar **422**, Fig. 17A. The hydraulic arms **450** on the other side of the central spine **420** pivot within a vertical plane in relation to the carrier. This combination is critical to avoid slab displacement.

Another embodiment of the present invention comprises additional fixed non-hydraulic arm members **422** attached to the central support spine on one end and pivotally joined or anchored to the carrier plate on the other end, Figs. 17 and 17A. In this embodiment, rigid support bars **422** may not be necessary.

The ends of the central support spine **420** attach to and are supported by mechanically controlled, height adjustable framed front and back carrier support mechanisms, **430** and **440**. One embodiment of the mechanism means for the replacement slab **1100** comprises a fixed worm screw threaded assembly with cross beams **486** affixed to the central support spine **420**. Alternatively, the mechanism means **450** for rotating the replacement slab **1100** comprises cable or rope and pulleys.

As depicted by the embodiment of carrier or transport trailer **400** in Figs. 17 and 18, when the carrier transport trailer **400** is in travel or transport mode, the mechanically

controlled, front and back carrier support and height adjustable mechanisms, **430** and **440,** are fully extended, and the cross-beams **486** and central support spine **420** are at a height of approximately 9 feet. Each carrier support mechanism, **430** and **440,** further comprises two ends. One carrier support mechanism end comprises an axle and wheel assembly, **490** for the front wheel assembly or **492** for the rear wheel assembly. The other carrier support mechanism end comprises fixed attachment to one end or the other end of the central support spine **420**. The front wheel assembly **490** further comprises a turning axle and tongue **498** which communicates with a tractor/truck transport means.

In the replacement slab **1100** placement mode, Figs. 15, 16, and 18, the carrier transport trailer **400** is positioned above the location for the slab replacement. The replacement slab **1100** has been first rotated to an approximate horizontal position and then lowered into the location for the slab replacement by the corresponding mechanism means for lowering/lifting **450** the replacement slab **1100**. Corresponding lowering of the central support spine **420** by the carrier support mechanisms, **430** and **440,** allows the front wheel assembly **490** and the rear wheel assembly **492** to raise off the ground whereby the entire carrier transport trailer **400** weight is transmitted to, and is positioned on, the support plate **480**, Figs. 16 and 18. The support plate **480** extends approximately one foot on each end of the slab length onto the planar surface of existing slabs **1200** in the highway in this placement mode, Fig. 18. The plate extension dimension or

plate thickness can be adjusted as necessary depending on the requirement to minimize slab sag or deflection.

Embodiments of carrier transport trailer **400** depicted in Figs. 14 - 19, or **500** depicted in Figs. 25 and 25, can be positioned into the hole to receive the replacement slab **1100** using guide ramp assemblies as depicted in Figs. 20 - 22, as similarly discussed above.

The guide ramps, Fig. 20, comprises an approach ramp **600** connectively hinged **610** to a ramp base **620**, the height of which is adjustably fitted according to the hole depth with steel pads **630**, if necessary. The ramp base **620** communicates with two equal sized and angled ramps **640** which, as depicted in Fig. 22, have equal sized channels **650** which correspond with the tire widths of the front **490** and rear **492** wheel assemblies of the carrier transport trailer **400**. As shown in Fig. 22, the ramps **640** are spaced to receive the wheel assembly dimensions by fixed distance attachments **670** attached to the corresponding ramp inner sides, and are secured into position by use of manually adjusted screw or similar securing mechanisms **660** between the ramp outer sides and adjacent existing slabs **1200**. The maximum width of the secured ramps **650** is approximately twelve feet, or adjustably to the particular replacement hole width dimension.

If time is of the essence, the present repair system can be used for concrete slab replacement by using plates and the carrier only without the injection guide collars and use of eye adjustment of the slab into place as practiced in the art.

The embodiments of carrier transport trailer **400** depicted in Figs. 14 - 19, and **500** in Figs. 25 and 26 are designed to use a preferred embodiment of collar plate **700**, as depicted in Fig. 23, for precisely guided placement of a replacement concrete slab **1100** within the space bounded by unaffected surrounding concrete slab **1200** planar top surfaces. The collar plate **700** comprises at least one raised slot bar **710** for the side collar **68** and collar extensions **720** to engage and move in or out to accommodate varying widths of replacement slab **1100**. The slot bar **710** serves to secure the collar extensions by vertically oriented bolts (not shown) built into the slot bar which are turned to secure the collar extension position once the side collar **68** is snugly positioned at the edge of the replacement slab **1100**. The collar plate top side further comprises a plurality of slots **730** to allow movement and support for the end collar **68** and collar extensions **720** to accommodate varying lengths of replacement slab **1100**. The collar **68** is under the collar plate **700** and extends nearly the slab width. The collar extensions **720** fit over and onto the collar **68** and fit into slots in the corresponding bar on the collar plate **700** top side, which hold the support collar **68** and extensions **720** below the plate so as to engage the replacement slab **1100**. The collar plate **700** corners **750**, provide spacial flexibility for differing sized collar add-in portions **760** to accommodate varying replacement slab **1100** sizes and are linked by removable bridges block-to-block **770** to the plate **700** and/or fixed collars, **68** to counter replacement slab uplift from

the injection of high strength grout or polymeric foam. In this manner, the collar plate **700** provides a sealing means to hold pressurized high strength grout or polymeric foam in place until high strength grout or polymeric foam has been uniformly and evenly distributed under the replacement slab. Additionally, the adjustable collar plate **700** can be used to inject high strength grout or polymeric foam from the replacement slab **1100** perimeter, or using the same mechanism in reverse, to verify whether high strength grout or polymeric foam has reached the replacement slab **1100** perimeter, or measure and control fluid binding material pressure density from the replacement slab **1100** perimeter.

As depicted in Fig. 23A, the collar **68** cross-sectional view shows the collar portion which snugly fits against the replacement slab to be the base of an approximate right triangle collar cross-sectional geometry. In this manner, as the replacement slab is positioned into the space vacated by the removed damaged concrete slab, the hypotenuse side serves to guide the slab into the space while keeping the collar **68** snug against the replacement slab sides within the desired width dimension of the joint gap, **69**. The collar **68** provides vertical oriented openings **68a** for injection of fluid binding material and/or taking pressure measurements of the same.

Both the end and side collars **68** of the collar guide plate of Fig. 23 are shorter to the corresponding length and width dimensions of the replacement slab **1100**. The side collar **68** and its corresponding extension **720** is much shorter because

replacement slabs in the United States range from 12 feet to 16 feet in length. The varying lengths are designed to prevent harmonic vibrations which have been shown to be transferred to vehicles causing the vehicles to skitter off the highway surface. U.S. replacement slab widths approximate 12 feet; however, widths typically vary by inches, not feet.

Another embodiment of transport trailer **500**, Figs. 25 and 26, comprises a horizontal cross member **550** hinged to the top portion of each of the front frame member **516** and rear frame member **517**. In this fashion, the support beam **512** is hinged to each frame member by attachment to the cross members **550**. Front **516** and rear **517** frame member heights are controllably adjusted by hydraulically controlled pivot mechanisms allowing each frame member bottom portion to extend independently outward from the carrier plate, horizontally along the frame longitudinal axis, thus transferring most of the frame carrier or transport trailer weight to the carrier plate when the replacement slab has been positioned for installation.

The present invention uses a large, bob-tail type truck with a 5 to 7 ton crane and a high strength grout or polymeric foam storage, stirring or mixing, and pressurized applicator mechanism mounted thereon. All bridge removal plates, collars, ramps, saws, and other components or tools needed for the apparatus and system of the present invention including, but not limited to, bar code readers, global satellite positioning instruments, grout pressure measuring devices, and the like, would likewise be

contained on this truck.

The apparatus and system of the present invention can remove and replace a failed concrete surface slab in about three hours; the methods in the art typically require eight to ten hours. The apparatus and system of the present invention can remove and replace a failed concrete surface slab with fewer laborers and less equipment. The present invention does not damage the supporting road base and provides a superior means to apply the interface high strength grout or polymeric foam. This improved slab replacement apparatus and system creates a smoother slab to slab vehicle ride and longer installed slab life - all at a reduced cost to remove and replace the failed concrete slab. And, most critically to the longevity of replacement slabs, the present invention addresses the need for precision repair work in replacing pre-cast concrete slabs in highways by insuring uniformity of: (i) grout density and distribution in the interface between the replacement slab and the roadbed; and (ii) the spacing tolerances between replacement slab and adjacent unaffected planar slab surfaces and boundaries up to the space vacated by the removed broken slab.

With respect to the above description then, it is to be realized that the optimum dimensional relationships for the components of the invention, to include variations in size, materials, shape, form, function and manner of operation, assembly, manufacture, and use, are deemed readily apparent and obvious to one skilled in the art, and all equivalent

relationships to those illustrated in the drawings and described in the specification are intended to be encompassed by the present invention.

Therefore, the foregoing is considered as illustrative only of the principles of the invention. Additionally, since numerous modifications and changes will readily occur to those skilled in the art, it is not desired to limit the invention to the exact construction and operation shown and described, and further, all suitable modifications and equivalents may be resorted to, falling within the scope of the invention.